United States Department of Agriculture,

BUREAU OF SOILS.

U. S. DEPARTMENT OF AGRICULTURE,
Washington, D. C., August 3, 1901.

SIR:

About six months ago Dr. L. O. Howard, the Entomologist of this Department, requested the cooperation of the Division of Soils in some practical demonstrations of the feasibility of getting rid of the mosquito pest in certain tidal swamps of the Atlantic Coast. Dr. Howard had been advising about the extermination of mosquitoes in an area around Oyster Bay, L. I., and requested us to investigate the character of the soils of the tide marshes and the possibilities of reclaiming them for agricultural purposes. Mr. Thos. H. Means, of the Division of Soils, was assigned to this work, and made a preliminary examination, the results of which are briefly described in this circular.

It is believed that the information contained herein is sufficiently suggestive of the possibilities of further work to warrant publication at this time, and that the seriousness of this problem along the whole coast is certain to demand attention in the future. The presence of the mosquitoes has been an important contributing cause to the abandonment of lands and the depreciation of property values along the Atlantic, Gulf, and Pacific coasts.

Respectfully,

MILTON WHITNEY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

RECLAMATION OF SALT MARSH LANDS.

INTRODUCTION.

Tidal swamps and salt marshes are a prominent feature in nearly all States which border the Atlantic or Pacific ocean. A few years ago much was heard about their reclamation. Their value as farming lands was clearly shown, and the fact that they were a serious menace to the health of people in the vicinity was dwelt upon. About this time several Government reports were issued. Notable among these reports were "Sea Coast Marshes of the United States," by N. S. Shaler, published in the Sixth Annual Report of the U. S. Geological Survey; "Tidal Marshes of the United States," by D. M. Nesbit, published as Special Report No. 7 of the U. S. Department of Agriculture, and numerous notes and reports in the publications of the New Jersey Geological Survey. Some of these reports are out of print and all are now difficult to obtain.

Within the last ten years investigations have been pursued by scientists in Europe and this country which have conclusively proved that

certain species of mosquitoes are the most common, if not the only, means of conveying malarial germs and of introducing those germs into the human system. More recently mosquitoes have been found to be the cause, and so far the only proved cause, of the infection of yellow fever. Marshes and stagnant pools of water are the principal breeding places of mosquitoes, and to remove the pests such places should be drained and the lands reclaimed for agricultural purposes. In Italy the mosquito pest has been the cause of the abandonment of vast areas of land. The salt marshes do not seem to offer the condition necessary for the breeding of the few species of malaria mosquitoes existing in this country, but they are breeding places for vast numbers of mosquitoes of other species which annoy the residents and stock along much of the coast line and in certain places impair the property valuation.

These recent discoveries of the cause of the infection from malaria and yellow fever have resulted in a renewed interest in the means of exterminating mosquitoes and incidentally in the drying out of marshes and swamps. The writings of Dr. L. O. Howard, Entomologist of this Department, on mosquitoes have aroused the interest of the inhabitants of mosquito and malaria infested localities in the subject of swamp reclamation; and this Bureau is in frequent receipt of letters inquiring about the agricultural value of the marsh lands and methods for their reclamation. A great many people seem willing to undertake the drainage of these marshes and tidal meadows if it can be shown to them that there will result a pecuniary profit. Therefore, to determine the agricultural value of these soils a trip was made to Oyster Bay, Long Island, where reclamation work was in progress. Samples of the soil and subsoil of the eel-grass mud were collected and subjected to laboratory examination. No elaborate study of the subject is possible at this time, so a simple statement of the conditions existing there is all that can be made.

The conditions are sufficiently typical of coast marshes all along the Atlantic coast to warrant the application to other localities of any lessons learned. The opinions of several earlier writers on the subject have been quoted, and it is to be hoped the value of marsh lands has been brought out clearly enough to direct more serious attention to their reclamation. Shaler[1] says:

> The great advantage of the northern marsh areas is found in the fact that they are generally near the larger centers of population of the country, where they will have a high value as market-garden soils or fields for the raising of hay. When brought into their best state such areas will, measured by the price set upon other lands in the same neighborhood, have a value of not less than $200 an acre. As the total reclaimable area between New York and Portland (Maine)

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[1] Sea Coast Swamps of the Eastern United States, U. S. Geological Survey, 6th Ann. Rep., p. 380.

probably exceeds 200,000 acres, the money value of their best state will amount to at least $40,000,000. The cost of reclaiming these lands and reducing them to cultivation should not exceed the fifth of this sum.

In European countries salt marshes are regarded as the most fertile of lands. Large areas in Holland, Denmark, Germany, and Belgium have been cultivated for many years. In England the Fens to the extent of probably more than 1,000,000 acres have been diked and ditched and are now in a "state of matchless fertility."

The reclamation of tidal lands to be successful at a minimum expense should be managed by a man of experience in such matters. The question of how to build dikes, the cheapest and most efficient method of drainage to be employed, and the subsequent management of the soil to bring it into a state of fertility at the earliest possible moment, are all problems which require experience and judgment if the work is to be a success. Unfortunately, in America there are no trained agricultural engineers, nor is there an institution of learning which claims to train expert agricultural engineers. The best person, then, to plan and manage the reclamation is a civil engineer who has had experience in some related work. Men of experience have a habit of charging well for their services, but the money spent in fees to the right man is well invested. Diking and ditching done by inexperienced or careless persons will require more in repairs each year than would have been necessary to insure proper supervision in the first instance.

Shaler (Loc. cit., p. 377) very aptly says:

> Where efforts have been made to exclude the sea and actually till the land they have sometimes been unsuccessful, owing to the failure of those who carried on the trial to see the true condition of the work. It is very much to be regretted that these experiments are not directed by some one trained in the work as it is effected on the northern shores of Europe, who could have brought to the task the accumulated experience of centuries; if this had been done it is tolerably certain that the process of turning these American marshes to agriculture would now be well advanced.

RECLAMATION OF TIDAL MARSHES.

The first step in the reclamation of tidal marshes is the exclusion of the sea. Ordinarily the marshes are covered by sea water only at high tide—some of them at every high tide and others only at the highest or spring tides. Salt water is harmful to most all plants and its presence in the soil will effectively prevent the growth of ordinary farm crops. To exclude the sea a dike or embankment must be built at least 2 feet higher than the highest tide. The method of building such dikes must, of course, depend upon the locality, the exposure to wave action, and the kind of dike-building material at hand. The material in most common use is the sod and soil from the marsh itself. It is cut from the swamp just inside of the position to be occupied by the dike and the exca-

vation acts as a drainage canal. The outer slopes of the dike should have a grade of at least $1\frac{1}{2}$ horizontal to 1 vertical and should be shielded from wave cutting by being well sodded with the marsh sod. On exposed shores, where the wave action may be great, special precaution should be taken to prevent washing by waves. The precaution may take the form of masonry work or stone facing in the more substantial dikes, or it may be a simple brush fence held in place by stakes driven in the ground. Various expedients of this nature, both cheap and effective, will suggest themselves to the engineer.

The ditch on the inside of the dike should be designed for drainage. This ditch is usually situated along the lowest portion of the marsh and is well placed to receive the lateral drains from the higher portions, and, being at one end of the field, it is of little obstruction in the way of cultivation. The dimensions of this ditch will be governed by the amount of material required to construct the dike, if the dike material is all taken from the ditch. A mistake is often made by digging the ditch too wide. Consideration must also be given to the amount of water emptying into the drains from the entire watershed and to be removed in a given time. It is very seldom necessary to remove more than one-half of an inch in depth of water in any twenty-four hours, and if the ditches are planned to carry this much water the drainage is good. Under certain conditions the open ditches should have a capacity of as much as one inch in depth over the entire watershed tributary to the ditch. The outlet of the main drains should be through the dike by means of an automatic sluice or tidal gate. Ample room for storage of the drainage water which may accumulate during high tide should be allowed and the sluice gates should be of at least twice the capacity of the main ditch, so that the entire drainage during high tide may be removed during the interval of low tide.

On exposed coasts, where the maintenance of an outlet would be difficult or when the drainage is desired at a level lower than the lowest tide, some other means of getting the water over the dike must be planned. Windmills have been favored in European countries and have been used in a small way in America. Various forms of pumps of cheap construction and of great efficiency are now in the market, and when driven by steam or gas engines are probably the cheapest form of water-lifting machinery and are not dependent upon the vagaries of the wind. Such a lifting plant need not be run all of the time, if storage of the drainage water can be allowed. The conditions are exceptional where the pumping is necessary during the entire growing season.

UNDERDRAINAGE.

Tile drains are the most effective means of removing water from land and in the course of time will prove the cheapest. Farmers' Bulletin

No. 40 of this Department treats of farm drainage, and more detailed information can be obtained from various publications on the subject.

In the ordinary condition in which tidal marshes are found it is unwise to place tile until the land has had opportunity to drain and settle; otherwise in the settling the tile will be displaced and rendered of little use. For this reason the ditches for the tile drains should be dug and allowed to work as open drains until the excess of water from the soil and the settling which accompanies the drainage is over. In cases of very peaty swamps this sinking is great and continues for a long time. More permanent open drains are then essential, but they should be maintained as open drains no longer than necessary.

The distances between the drains will vary with the soil. In light porous soils a distance of 300 feet is allowable, while in stiff and tight clays drains 30 feet apart are sometimes necessary. The minimum depth should be 3 feet for general farming or trucking, but for grass land the drains are as effective if placed not deeper than from 18 inches to 2 feet. In peat soils drains one-fourth to one-half mile apart are often sufficient.

The grade on which the tile is to be laid is largely to be governed by the height of the marsh above low water. The tendency is to use very few of the 1½-inch or 2-inch tiles, but to make 3-inch tiles the smallest used. The smaller tiles are found difficult to lay and keep in operation and the 3-inch tiles are not more expensive in the end and are much more effective.

WASHING OUT THE SALT.

In salt marshes the tile drains are for two purposes: First to remove the salt which has been left by the water, and second, to remove promptly any excess of water which may be present or fall on the marsh. In order that the salt may be removed it must be dissolved in water and that water drained away. The usual way of reclaiming the meadows is to allow the rain to wash out the salt. This is a slow practice, requiring usually two or three years, but during this time some crop can usually be grown. The sweetening can be accelerated by irrigation with fresh water, if such is at hand. When the land is to be reclaimed by irrigation small amounts of water should be applied at frequent intervals rather than a single heavy flooding. If small applications of water, not more than enough to cover the ground to a depth of from one to 4 inches, with sufficient time between the applications to allow the drains to carry away all the excess of water, be applied, the land can be sweetened in one season or less. If the natural sweetening process is followed, the native salt grass should be allowed to grow at first and tame grasses will gradually take their place as the salt is removed by the drainage.

When the cost of this method of frequent small floodings is found to

be prohibitive the land may be flooded to any depth and that depth maintained. Reclamation in this way is successfully carried on, but only water-loving crops can be grown during the sweetening process.

CULTIVATION OF MARSH.

After the land has been diked and ditched the best method of cultivation must be settled upon. If the soil is a tidal mud or silt, without a covering of any kind, the cultivation can be commenced at once or at least as soon as part of the salt is leached out. A great variety of crops is adapted to such soils. Cleaning the land of all weed seed and giving it an opportunity to be thoroughly aerated and weathered, by planting for one or two years some cultivated crop, such as corn or sorghum, is recommended. After that time, the best crop to select is one suited to the locality; whether it be truck, hay, cabbage, celery, or small fruits will depend on the market and taste of the cultivator.

If, however, the tidal silt or mud, or eel-grass clay, as it is generally known, is not at the surface, but is covered by a sod formed of the partly decayed stems and roots of the salt grasses, a very different method of treatment is necessary in order to get the soil in condition to cultivate. If this sod is thin and well rotted, disking, deep plowing, and thorough cultivation will generally break it up and enable a good seed bed to be prepared; but when it is a foot or more deep, and is in turn underlain by half decomposed sod for a depth of a foot or two, the breaking up and incorporation with the underlying soil in a short time by cultivation are impossible. The best method of subduing such soil is to burn off the sod. When it is fairly dry to a depth of 12 inches fires should be started at a number of places and the sod allowed to slowly smoulder. The burning should be carried on until the eel-grass clay is close to the surface, or until the heavy roots are consumed. Then by rolling and plowing the soil can be worked into condition. Burning was formerly a practice in common use in European agriculture, and is yet continued in the marsh soils of northern Germany, Denmark, and Holland. The smoke of this burning is said at times to be noticeable as far as Italy. The sod is there burned to a depth of 10 or 12 inches only, and is then cultivated for from five to ten years and burned again.

Such a practice will in time burn the entire peat of the swamps and leave the underlying soil bare. The practice is very prodigal of organic matter and is not to be recommended in America, especially since there are crops which grow to best advantage in peat. In celery areas, where such peaty soils are handled, burning is not the usual practice; in fact, the organic matter is the desirable part of the soil for the production of celery. In such areas some cultivated crop is planted for one or two years to give the peat an opportunity to decay. Rather

shallow open drains are dug and the soil slowly dried out. When the first plowing is done the peat is often wet and boggy, so that it is impossible to drive a horse across the bog. Ingenious farmers in California attach a board to the feet of the horse the first time a bog is plowed. Though most horses are not used to working with "tule shoes," as they are called, they soon learn the proper swing to give the feet and the work of plowing goes on nicely.

The judgment of the farmer must be the guide as to the best method to be used to bring the land into good tilth. As a rule burning is a waste of organic matter which in the later years of cultivation will be needed. However, it is frequently better policy to burn off troublesome sod and trust to later stable or green manuring to keep the supply of organic matter up to the standard.

As a rule salt marshes are well supplied with lime in the form of shells. Such soils in decaying will not need to be limed. Sometimes, however, the shells are not present and the soil is either acid in its natural condition or soon becomes so through the decomposition of the organic matter. Lime is then necessary to correct the acidity. Either shell marl or shell lime is usually obtainable at low cost near the coast.

Sulphide of iron is sometimes present in marsh lands and by its decomposition gives off hydrogen sulphide gas and soluble iron compounds or sulphuric acid, all of which are harmful to plants. Thorough aeration will remove the hydrogen sulphide, but the poisonous iron compounds are more difficult to get rid of. Weathering and aeration with the application of lime, both as carbonate and sulphate, are the best methods known for the correction of the toxic effect of iron in the soil. The iron is most often found only in spots and small areas which slowly yield to cultivation. Very seldom does it cover large areas.

CROPS DURING RECLAMATION.

As has been stated before, the easiest method of reclaiming the salt marsh is to make the best use possible of the native salt grasses and to allow the tame grasses to come in as the salt is removed by drainage. This process can be accelerated by seeding with small quantities of tame grass—timothy, red-top, and the rye grasses are all good—on the parts of the marsh which contain the least salt. Three years will probably be the maximum time required to get a stand of tame grass. If the time needed to complete this natural reclamation is too long the process can be hastened by irrigation to assist in washing out the salt, or salt-resisting crops may be planted. Asparagus, onions, sorghum, and beets withstand large quantities of salt in the soil, and if the soil is such as to be acceptable to any of these crops they will prove profitable.

AGRICULTURAL VALUE OF SALT MARSHES.

To determine the agricultural value of such lands several samples of the salt marsh areas around Oyster Bay, on Long Island, were collected and subjected to laboratory examination. These are very probably representative of much larger areas of salt marsh, and the results of their examination will no doubt prove of interest to owners of salt marshes all along the coast,

As has been indicated, there are many kinds of salt marshes and tidal flats—some merely bare mud flats without vegetation, and others with a heavy growth of grass and with a sod a foot or more thick. In any locality such differences are due to the age of the marsh, and the two cases mentioned can be considered as representing youth and old age in marsh growth.

Mechanical analyses of tide marsh soils from New York.

Locality of soil.	Sand.	Silt.	Clay.
	Per cent.	*Per cent.*	*Per cent.*
5379. Mud from tidal flat, west end Lloyds Harbor, 0-6 inches	13.2	44.8	42.0
5375. Subsoil from outer marsh, Center Island, 36-66 inches	28.0	44.9	27.1
5378. Subsoil from inner marsh, Center Island, 24-72 inches	38.0	37.1	24.9

Chemical analyses of tide marsh soils from New York.

Composition.	5379 Soil 0-6 in.	5374 Soil 0-36 in.	5375 Subsoil 36-66 in.	5376 Soil 0-12 in.	5377 Subsoil 12-24 in.	5378 Subsoil 24-72 in.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Lime (CaO)	0.43		0.31			0.41
Potash (K_2O)	0.57		0.57			0.68
Phosphoric acid (P_2O_5)	0.16		0.14			0.12
Organic matter	7.18	29.00	5.36	34.70	25.49	10.90
Soluble in water	2.16	4.07	2.55	1.87	3.87	3.56

The two tables show the results of the laboratory examinations of the Oyster Bay samples. Sample No. 5379 was collected from the tidal mud flat in the west end of Lloyds' Harbor, and represents the soil on which the salt marsh grows, or, in other words, is the salt marsh in youth. At low tide this mud flat is only a foot or 18 inches above the level of the water in the harbor, but at high tide it is covered with salt water 4 or 5 feet deep. At the present time the eel-grass has just commenced to grow on the mud, and it is found in large, round hummocks dotting the mud flat. These hummocks will gradually spread until the eel-grass is growing over the entire flat. The growing grass greatly retards the flow of the water as the tide rises and flows and the deposition of the sediment will be hastened. The chemical analyses of this mud show it to be fairly rich in lime, abundant in potash and with an adequate supply of phosphoric acid. The 7 per cent of organic matter will keep the clay soil in good tilth. The

amount of soluble matter (2.16 per cent), which an analysis showed to be almost entirely from sea water, would prevent useful plant growth other than salt grasses. The drainage of this flat would permit the washing out of this salt.

Two marshes on Center Island which are being drained were examined. These marshes—an inner marsh and an outer marsh—are separated by a narrow neck. Across this neck a causeway had been built and sluice gates placed in the culvert under the causeway. The gates were not carefully watched and the tide water backed up on the inner marsh several times. Notwithstanding this, the inner marsh was much fresher. The outer marsh, however, was covered at high tide twice a day and contained a large amount of salt. Both of these marshes had a sod about 1 foot thick and below this was decomposing sod to a depth of 3 feet and then came the eel-grass mud, very similar to that collected in the west end of Lloyds Harbor.

Samples No. 5374 and No. 5375 were taken from the outer marsh and represent the sod and decomposing grass roots and the underlying eel-grass clay, respectively. The plant food analysis of the clay shows it to be similar to the mud from Lloyds Harbor. The amount of soluble salt in both soil and subsoil is seen to be high for plants other than salt grasses. The sod is so light and tough that to decompose it thoroughly for a seed bed would require several years; therefore, it is likely that burning will be found the best method. It is interesting to note that the burning of these salt marsh soils causes part of the soluble matter to disappear, so that afterwards the amount of soluble matter is smaller than before burning.

Samples No. 5376, No. 5377, and 5378 were collected from the inner marsh. The first two are the sod and decomposing sod, respectively, and the last is the underlying eel-grass clay. The plant food analysis shows this clay to be very similar to the Lloyds Harbor mud. The percentage of soluble salts in the surface foot of the inner marsh is lower than that in any of the other samples. This shows that a start toward sweetening has been made by the simple shutting out of the sea water. The drainage of this inner marsh is in progress and three samples of the drainage water collected while the ditch was in process of construction showed a salt content of 525, 860, and 860 parts salt per 100,000 parts of water. If this drainage keeps up the marsh will in a short time be much sweetened. The soil in this inner swamp is also very light and should be burned if the intention is to cultivate it.

SUMMARY.

Salt marsh lands have long been considered the most fertile and valuable of lands. Practically no reclamation has been attempted in America, and that which has been attempted has in many cases been

a failure or has been abandoned. There are well established methods in use in the reclamation of salt marshes and if these are used the work should be successful. There has never been a known case of failure to effect complete reclamation, in which all proper precautions were taken. After reclamation the lands are very fertile and should repay the expenditure for reclaiming them. It is generally conceded that 1 acre of reclaimed salt marsh land is worth 4 or 5 acres of upland, and, according to the well substantiated figures quoted from Shaler earlier in this article, the cost of reclamation should not exceed one-fifth of the final value of the land.

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